



As we constantly become more and more nearly lords of creation, there is nothing so much to be feared as ourselves, yet we know so little about fearsome us.

Howard Zahniser, quoted in *John Muir and His Legacy*, 1970

### Last Supper for Mosquitoes

The same pond scum that nourishes young mosquitoes soon may deliver their death blow. A newfangled version of the common algae *chlorella* has been bio-engineered as a mosquito larvicide. The larvicide's effect comes from a hormone that shuts down digestion. Because the hormone occurs in mosquitoes naturally, researchers believe the new larvicide poses none of the environmental risks of older methods. "It's a natural hormone," explains John Bennett, chairman and CEO of Insect Biotechnology, a Chapel Hill, North Carolina-based corporation that has licensed the larvicide technology from the University of Florida in Gainesville, where it was developed.

"This is a green product—safer than chemical pesticides used today."

Dov Borovsky, a biochemist at the Florida Medical Entomology Laboratory in Vero Beach, discovered that in nature, trypsin modulating oostatic factor (TMOF), a peptide hormone, normally shuts off the production of stomach enzymes in mosquitoes after a blood meal has been digested. Young larvae that were fed the hormone stopped digesting food prematurely and quickly starved to death.

Borovsky and his colleagues packaged his mosquito "diet pill" in the freshwater *chlorella* algae favored by waterborne larvae. The hormonal protein gene is incorporated in the DNA of the genetically altered *chlorella*.

Borovsky claims that TMOF is effective against most species of mosquitoes, including those that transmit dengue fever, yellow fever, St. Louis encephalitis, eastern equine encephalitis, and malaria.

TMOF has yet to be tested in the field. Bennett expects to begin small field trials within the next four months and continue



**Languishing larvae.** A new strain of *chlorella* may prevent mosquito young such as these *Aedes aegypti* larvae from growing up to become disease carriers.

*thuringiensis* ssp. *israelensis* (Bti) and the growth hormone methoprene, sold under the brand name Altosid. Both are considered environmentally safe, although studies suggest they kill some nontarget aquatic insects. "We found that with long-term, high-level applications, some midges [gnat-like flies] are affected," says Nancy Read, the technical leader of a study of the effects of larvicides for the Metropolitan Mosquito Control District in St. Paul, Minnesota.

Another possible drawback of Altosid and Bti is resistance. "When you're using only one or two insecticides, the probability of resistance is strong," says entomologist Kelly Johnson of Ohio University in Athens. "An arsenal of more tools is better." Borovsky says he's heard of Altosid resistance problems in several mosquito-control districts in Florida.

In many developing countries, the larvicide temphos, sold as Abate, is often used because it costs considerably less than Bti and Altosid. But the broad-spectrum organophosphate weakens the food chain by killing other waterborne arthropods and copepods.

until the EPA's requirements for registration are satisfied. But already the new larvicide is creating a stir in the mosquito-control community. Since word of his development hit the Internet, Borovsky has received calls from people as far away as China, India, and Singapore.

"We could sure use alternatives," says Andrew Spielman, a professor of tropical public health at the Harvard University School of Public Health in Cambridge, Massachusetts. "If you could have a transgenic alga that expresses the [TMOF] protein, it would be very attractive."

The most commonly used mosquito larvicides in the United States, according to Spielman, are *Bacillus*

Borovsky believes his larvicide is a safer choice, not only because the hormone occurs naturally in mosquitoes, but also because its pond life is limited. The genetically altered variety of *chlorella* is believed to carry the hormone only through a few generations, lasting a total of 3–4 weeks. "The gene we put in is not stable, so eventually the dividing *chlorella* will kick it out," Borovsky says. "You don't want something [like that] to stay in the water forever." Spielman and Johnson agree. "I think it could be a good delivery system if there's tight control over the *chlorella*," Johnson says.

Spielman cautions that mosquitoes might develop resistance to TMOF as they apparently have to methoprene. Borovsky points out, however, that methoprene is an analog that binds to a different receptor than does the natural form of the hormone. He doubts mosquitoes will resist his *chlorella* larvicide because it contains the same hormone they produce naturally.

A significant limitation of Borovsky's larvicide is that *chlorella* grows only in fresh water. Borovsky is experimenting with other delivery vehicles that can be used in saltwater marshes. He is also investigating the digestion-regulating hormones of budworms, diamondback moths, and other pests. He expects his research to one day greatly lessen the need for chemical insecticides. "Insects are regulating their digestive enzymes," he says. "We are looking at these regulators. I see that in the 21st century we're going to control most of these pest insects through natural hormones."

### The Threat of Meth

In January 1996, a large mobile home in Aquanga, California, burst into flames after a home methamphetamine lab exploded. Kathy James, her son Jimmy, and two men managed to scramble out, but trapped inside and suffocating to death were James' three younger children. Then, in September 1997, toxic fumes from a home lab killed little Joseph Carnesi in a Phoenix, Arizona, apartment as he slept on a couch. These are just two of many such incidents graphically illustrating the growing environmental health danger of the home meth labs that have sprung up across the country in recent years.

Meth labs, in fact, have become known in law enforcement as the hazardous waste sites of the drug trade. "Almost every day, people are arrested who are willing to risk their lives and those of their children," says Thomas Abercrombie, assistant laboratory director at the Bureau of Forensic Sciences in the California Department of Justice. "They usually don't have a clue what those chemicals can do to them."

In California, where meth manufacturing in the United States is largely centered, hospital admissions due to methamphetamine-related causes rose by 360% between 1986 and 1996. These patients included victims of fires, chemical spills, explosions, and the inhalation of toxic fumes. In December 1997, federal drug agents raided one meth lab in Los Angeles where the combustible and toxic chemicals were still cooking. Across the street was a day care center; nearby were two public schools.

Experts describe meth as the "poor man's cocaine"—a cheaper drug that gives people a longer high. "It's easy to manufacture," says Tom Cashman, a special agent with the United States Drug Enforcement Administration (DEA), who is the agency's leading expert on methamphetamine. "Amateurs can cook it up with a few chemicals in a makeshift lab. You don't need a lot of space or sophisticated equipment either. That's why it's being cooked in a variety of settings: apartments, cheap motels, mobile homes, and isolated farms and ranches."

It takes just \$4,000 in raw ingredients to make eight pounds of meth, which is worth \$50,000 on the street. Most of these ingredients are obtained from drug companies or the black market, or distilled from other substances, depending on the meth "cook"'s contacts and resourcefulness. While most of the chemicals needed are not dangerous by themselves and can thus be easily obtained and manufactured, they create numerous environmental health hazards during the production process and after-

wards, when the chemicals are discarded.

Hydriodic acid and red phosphorus, the most dangerous chemicals used in meth production, can produce toxic phosphine gas and hydriodic acid vapors, while exposure to or inhalation of ether can cause respiratory damage, chemical burns, and even death. Red phosphorus poses additional problems because it's unstable and flammable, and can cause explosions and chemical fires if exposed to a flame or spark.

The fact that the meth-making process is getting easier has encouraged more people to get into the illegal activity. A recently unclassified DEA report reveals that phenyl-2-propanone (P2P) has been the primary precursor for meth manufacture. Since 1990, however, it has been increasingly replaced by the ephedrine reduction method, a simpler procedure that involves fewer chemicals.

Rod Oswalt, a forensic scientist with the California Department of Justice, points out that the information for making meth is widely accessible. "The Internet contains thousands of recipes and discussions on how to make meth," he explains. "This, no doubt, has been a big factor in the rising popularity of meth."

The post-manufacturing phase poses the additional problem of what to do with the hazardous waste generated in making meth. One pound of finished meth normally produces 5–6 pounds of waste that includes corrosive sodium hydroxide solution, sealed cans containing residual freon and other hazardous fluids, and even pillow cases and bed sheets—used for filters—that hold large traces of red phosphorus and hydriodic acid, which can remain an environmental threat for years.

Cleaning up such hazardous waste sites is expensive, too. "It costs the taxpayers \$5,000–7,000 every time we clean up a [meth lab] site," reveals Mike McCorson, an Arcadia, California-based hazardous waste coordinator for the Angeles National Forest.

Removing the containers, contaminated apparatus, and other typical waste is only a part of the cleanup cost. Cleaning a building, for example, can involve removing carpet, washing the walls, and removing or cleaning the drywall and the wood stud framing. In one incident, the Los Angeles police found that meth manufacturers had used a garage adjoining a private residence. Due to the proximity of the lab, the contamination extended to the house. The final cost of cleanup was more than \$45,000.

Responsibility for cleanup costs is one of the biggest issues regarding methamphetamine, and varies from case to case, and state to state.

Law enforcement officials nationwide foresee no letup in the meth lab environmental problem. Says Rodney Pickel, an antinarcotics officer with the Rock Hill, South Carolina, police department, "Right now, meth is the drug of choice in mainly California, but that state usually sets the trend for the rest of the country when it comes to drug abuse." And where there is demand for drugs, supply follows, creating even more opportunities for environmental disasters.

## A New Side of the Nicotinic Receptor

As the "decade of the brain" approaches an end, that wrinkly organ remains largely uncharted territory. But recent studies by two NIEHS researchers may lay important groundwork toward understanding the molecular mechanisms behind such neurological disorders as Alzheimer's disease, depression, epilepsy, and Parkinson's disease. Jerrel L. Yakel, a scientist in the Laboratory of Signal Transduction at the NIEHS, and Susan Jones, formerly of the NIEHS and now a postdoctoral fellow in the department of neurobiology at Duke University in Durham, North Carolina, have reported a study in the 1 November 1997 issue of the *Journal of Physiology* that reveals a previously unsuspected location and role for the brain's receptor for nicotine. By gaining a clearer understanding of the function of this receptor, it may be possible to devise more accurate methods for treating neurological disease.

The nicotinic receptor, one of two main categories of acetylcholine receptor, is a specialized ion channel that plays an important role in learning, memory, and survival- and stress-related responses. Ion channels function as "portholes" in the membranes of cells, opening or closing in response to chemical signals from outside, and therefore regulating the flow of electrical current through the cells. Says Yakel, "Our data provide a new mechanism to be considered about how the function of these ion channels, gated by the endogenous neurotransmitter acetylcholine or an exogenous activator [such as] nicotine, can act to regulate neuronal activity in a region of the brain—the hippocampus—that is believed to be a very important center for learning and memory."

Yakel's earlier work includes research on the role of the serotonin receptor in the brain. The Yakel-Jones study sought to



**Cottage industry?** Home labs (left) frequently use commonly available ingredients (right) in the production of illegal methamphetamine.

Jackson County (Missouri) Drug Task Force